International Review of the Auger Project

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1. Introduction

The review of the Auger project was carried out between Oct. 27 and Oct. 30 at Malargüe. Task leaders and project management addressed the state of the project and the plans and schedules in 15 presentations, followed by intense discussions. The review included tours of the assembly building with its assembly area, electronics shop, and water processing plant, of the office building, of the surface detectors of the engineering array and of the fluorescence detectors at Los Leones. Members of the panel in addition had a chance to attend the opening ceremony of the office building.
The central questions addressed in the review were

- the status and performance of the engineering array
- the ability of the collaboration to successfully construct, deploy and operate the full Auger system, with 1600 surface detectors and up to 30 fluorescence telescopes.

The issue of a northern array was discussed, but the committee feels that at this point it cannot make a strong recommendation. The collaboration itself has not yet resolved its position and its options on this issue. The collaboration plans to address this point at their next meeting in mid-2002.

2. The Auger Collaboration and the Auger Campus

The Auger Collaboration currently encompasses over 200 individuals from 50 institutions and 18 countries. The review panel felt that the general spirit of the collaboration is excellent and that the Auger collaborators at all levels were highly motivated and dedicated to the project. The panel was impressed by the very visible contributions of the Latin American collaborators, as well as by the engagement and degree of presence of the American and European groups. The project is clearly not a foreign entity in Argentina, but is integrated into both the scientific and the local community, has an excellent reputation and is viewed with pride. Members of the committee could attend the official opening of the new office building donated by the University of Chicago, where the large attendance both by citizens of Malargüe and by officials from the city and province demonstrated the highly successful integration of the project, and the efficient cooperation with local bodies at all levels. The Auger campus with its stylish office building and the functional assembly building provides both a well-equipped working place for the Auger scientists, engineers and technicians, as well as a central hub for public relations work and outreach programs.

3. The Engineering Array

The Engineering Array consists of 40 surface detectors coupled with the Los Leones fluorescence detector station currently equipped with two telescopes. The Engineering Array serves to

- test and refine the technical implementation of the detectors
- test the procedures for assembly and deployment

- provide an overall test of the systems integration and of the concepts for communications, control, and data recording.

The engineering array also provides a stringent test of the ability of the collaboration to organize its tasks, and to function in a environment which is new for almost all participants, remote from the big accelerator laboratories with their technical support. The collaboration has passed this test very well, and while the Engineering Array has not quite reached all its milestones, the progress during the last two years is very impressive, and the collaboration is to be congratulated for this success. At the time of the visit, all 40 surface detectors were installed, 28 were operational and sending data, with about 2-3 detectors being added each week, and the two fluorescence telescopes had taken data and tested their calibration procedures. Using a laser to generate an artificial light track and at the same time feeding some of the laser light into a surface detector tank, coincident "events" were registered, demonstrating the proper function of the trigger and time stamping systems and the ability of the data acquisition system to forward triggers from one component of the experiment to another, and to request and collect the relevant data segments from both the surface detector and the fluorescence detector. Auger will routinely operate such a hybrid system for the first time, greatly improving the ability to reconstruct showers and to reduce systematic errors in the energy determination. Experience gained with the Engineering Array is very valuable and has both demonstrated the viability of the detector concepts, and has resulted in numerous improvements in the technical implementation and its details. The committee is convinced that the final milestone, the stable operation of the Engineering Array for at least a few weeks and the detection of coincident air shower events in the surface and in the fluorescence detectors is well within reach in the last months of 2001. Towards this goal, the collaboration has rightly decided to freeze the detector configuration as of Nov. 15, at which time about 35 surface detectors are expected to be operational, and to transit to a state of stable data taking.

3.1 The surface detectors

The design of the surface detector stations is sound and appropriate. The adoption of a rotation-molded polyethylene tank promises to be a cost-effective and long-term stable solution, and while the initial tanks showed various problems, the collaboration has accumulated an impressive amount of expertise in this area and has been interacting intensively with the manufacturers. Current tanks are not perfect, but certainly useable, and the next generation of tanks is very likely to provide the final solution, optimised in all details. The same holds for the liners enclosing the water and connecting to the photomultipliers. Solutions used in the first tanks of the Engineering Array were somewhat marginal, and the original idea to produce liners had to be abandoned, but improvements in the current version address all questions raised, e.g., in the Technical Design Report, and there is now a stable and viable solution.

The sealed detector liner system and water purification system have been designed with the goal of maintaining optical quality water over the lifetime of the experiment. This requires high initial purity, careful choice of materials that come in contact with the water and the prevention of biological growth. With these measures, it is hoped that any organisms that are originally in the detector will be deprived of nourishment and will not multiply. Initial experience with the Engineering Array seems to validate this approach. The water for filling the surface detectors is produced and sterilized using industry standard techniques and is stored in a holding tank at the central campus. While in the holding tank, the water is recirculated through a resin deionization system to maintain very high quality. Currently, a single truck with a fibreglass tank is used to transport the water to the detector site where it is pumped into each detector. At the full deployment schedule, it will be necessary to enhance the water system in order to double the water production rate. It will also be necessary to increase the number of water transport trucks and tanks.

The surface detector electronics is well adapted to its tasks and exceeds the specifications in many respects. Thermal and temporal stability is very good, and so are noise levels and noise immunity. Trigger rates from the detectors are rather stable and reproducible, and the thresholds achieved for the peak 20 Hz trigger rate per detector are at or below design levels. Only the GPS-based time stamping of the events showed occasional jumps; while the effect is not fatal for the performance, it is under intense investigation by a task force; the committee is confident that the source of the problem can be identified and fixed before the electronics goes into pre-production. The packaging of the electronics of the engineering array, using many independent boards, was chosen both to ease modifications, and for historical reasons; the repackaging of the electronics onto a single digital board and an analog daughterboard is underway, but represents a major modification. Cabling of the various components on the Engineering Array detectors is intricate and will be revised for the pre-production detectors to improve reliability and ease of deployment. The supply scheme using battery-buffered solar panels has been proven to work reliably, and will supply detectors for over a week even under adverse weather conditions.

Both due to delays in the production of the electronics and due to unexpected difficulties in the deployment of the Engineering Array detectors - seasonal heavy rainfalls resulting in a flooding of access routes and deployment areas - the actual deployment procedure differed significantly from both the plans for the engineering array, and from the strategy foreseen for the full array. In the good-weather seasons, tanks had to be deployed without the phototubes, to be equipped, tested and commissioned later in the field.

Once commissioned, the detectors worked well, and did not show significant operational problems apart from occasional damage of outside connectors and cables by cattle. This problem will be addressed by design modifications, see above. Reliability of the detector operation was governed by the stability of the software, and after initial improvements and bug fixes, the detectors are up and stable for well over a month, since mid-September, with an accumulated exposure of two detector-years.

3.2 The fluorescence detector

The Auger fluorescence detector supplies fluorescence detector – surface detector hybrid data for a precision determination of shower parameters for 10 % of the total data sample and at the same time serves as the calibrator for the energy and the particle mass separation of the primary cosmic rays.

A total of 30 wide-field-of-view Schmidt telescopes deployed in 4 stations will cover the entire surface detector area. One such station was constructed at Los Leones for the engineering array and two telescopes were installed. The committee was impressed by the quality and the speed of the work done by the well coordinated collaboration. Significant numbers of air shower events have already been registered by the fluorescence detector alone. The electronic noise level was well below the night sky background.

The Los Leones building supplies good environmental conditions for protecting the sensitive telescope elements, including air conditioning and safety interlocks. The motivation for the latter was strengthened by a valuable experience of burning a small number of photomultiplier tubes (PMTs) by accidentally opening the telescope shutter window to sunlight at the initial stage of engineering array operation.

Several changes of the fluorescence detector design have been suggested by the operational experience of the engineering array. One of them is a redesign of the PMT camera to ease access to damaged PMTs for replacement. Another consists in removing a DC background measurement circuit at the PMT base which may make the system more prone to noise pickup. The use of a corrector ring extends the telescope aperture from 1.7 m to 2.2 m in diameter but the final design is yet to be fixed. In summary, the committee is convinced that the basic mechanical, optical and electronic design of the telescope is a proven system ready for commissioning and operation at Los Leones, and the fluorescence detector system is ready for production after adopting minor technical modifications.

The calorimetric determination of shower energy by the fluorescence detector requires the absolute calibration of the telescope elements such as the mirror reflectivity, the filter transmittance, the PMT quantum efficiency and the gains of PMTs and the electronic system. The group is promoting an interesting method of an all-in-one in-situ calibration by attaching a large diffused- light panel illuminated by a UV emitting LED, with the absolute luminosity calibrated relative to a laboratory standard. It has been tried with the Los Leones telescope and the present level of accuracy is claimed to be approximately 20%. This will be cut down significantly with better understanding of the system in future.

3.3 Communications, data acquisition, software, data analysis

The difficult issue of communication between primarily the 1600 surface detector stations and the Auger campus has been solved with brilliance using a custom radio design. The system is very efficient in terms of cost, power consumption and use of the available bandwidth, and allows a collision-free transmission of information from and to the detectors through the use of interleaved time and frequency slots. The sophisticated radios are essentially in their final form and their performance has been successfully demonstrated within the Engineering Array. At the higher level of the communications system, proven commercial components are employed. Telecommunication towers and antennas are installed on the Auger campus and at the Los Leones site; the high-bandwidth backbone and its interface to the custom radio system are in routine operation. A voice transmission system has been installed which will ultimately cover the entire Auger site and which is indispensable for the deployment of detectors and safety of personnel working in the field. This committee is convinced that the communications issue is more than adequately solved.

Working versions of the software of detector control, data routing, triggering and event assembly exist. The architecture of the central data acquisition system (CDAS) is modern, modular and flexible; the system is expected to meet or exceed the performance requirements and it provides suitable tools for data monitoring and visualization. Currently, these systems are (at best) “expert friendly” and significant effort is required and ongoing to make them user friendly. Apart from the general remark that here like in most other projects the software groups will have to work hard in order to keep up with the progress in the hardware area, this committee has no specific worries. In the analysis area, the committee encourages the management to push for the completion of the transition from individual data and event formats to the common unified framework; user friendliness and performance will be important in convincing users to switch.

4. Construction, deployment, and commissioning of the full Auger detector

Within the short time of little more than two years, the Auger collaboration has convincingly demonstrated the intellectual, technical and organisational capabilities necessary for the installation and operation of the Engineering Array. The collaboration has built up an amazing degree of knowledge and expertise in the areas relevant for the mass production of the detectors, down to technical details like the optimisation of rotomolding procedures. The task groups are led by highly competent individuals, and the project is well organized; a more detailed appraisal of the project management will be given in a later section. The committee is convinced that the collaboration will be able to successfully built, commission and operate the full hybrid system of 1600 surface detectors and four fluorescence stations.

The schedule, which calls for the production and deployment of the detectors by September 2004 is very aggressive, but not considered impossible by the committee. Timely delivery of all components seems possible, provided a suitable funding profile is maintained. The surface detectors are considered most critical. The first half of 2002 will show if it is possible to ramp up assembly and deployment procedures rapidly enough to move toward the full deployment rate of 100 to 120 surface detectors per month, and to start massive deployment in the dry season beginning with September 2002. The envisaged net deployment rate corresponds to 60-80% of the rate possible under ideal conditions. This might be achievable, but requires the absolute minimization of dead time due to broken down delivery trucks, failures of the water plant, etc. A delay in the schedule would cause the deployment of the last surface detectors to slip beyond September 2004, into the dry period of good deployment conditions, which will make it easier to catch up. There is no strong reason why the project absolutely needs to achieve complete installation in 2004; there is no serious competition on this time scale and given the envisaged data collection period of 20 years, a delay of, say, 6 months will hardly be detrimental or demotivating. While the committee certainly encourages the collaboration to attempt to meet the current ambitious schedule, the collaboration management must ensure that the experience gained with the pre-production detectors will be properly evaluated and taken into account in the full production. Premature production resulting in quality problems in a large number of production detectors will pose a much bigger problem than a small delay, which would at worst add to the manpower costs for temporary labor.

The current funding profile does not fully match the requirements for full production in 2002, and strong efforts should be made to ensure that funding is not only available at the level currently promised by the various funding agencies, but that funds currently scheduled for 2003 can be partially made available in 2002. A delay in detector deployment in 2003 and 2004 would not obviate the need for a sufficient funding level in 2002, required to ramp up the detector production.

4.1 The surface detector

The schedule for the surface detectors foresees the production and deployment of 100 "pre-production" detectors in order to validate the design modifications, to train and streamline the assembly and deployment procedures, followed by the full production. Pre-production is scheduled to last until the middle of 2002, with deployment rates of about 20 detectors per month, compared to production deployment rates in excess of 100 detectors per month.

The experience of constructing, deploying and commissioning the surface detectors of the engineering array resulted in numerous detailed improvements, the most noticeable one being a complete repackaging of the electronics in order to reduce the number of cables and feedthroughs, and to consolidate all functions on two boards, a digital motherboard and an analog daughterboard. Issues which were open at the level of the Technical Design Report, such as the production of the liners and details of the tank, appear to be solved. Given that almost every piece of a surface detector - up to the screws and seals holding the lids - will be improved, the committee strongly supports the view of the Auger management to start with a pre-pre-production series of about 10 tanks, and then move to the full pre-production of about 100 tanks, to be followed by the full production. Since the first 10 tanks of the final design should be commissioned before significant further production steps are taken, the new intermediate step might delay the deployment schedule by about 2 months, but will pay off in the long run. While the committee feels that the additional step is crucial in particular for the electronics, launching into a full production of the rotomolded tanks in early 2002 is considered appropriate, since potential further small improvements can be implemented on the fly.

4.2 The fluorescence detector

The group decided to use two types of mirrors; a laminated Aluminum mirror from Germany and an optical glass mirror from Czech Republic. Both of them satisfy the specifications and two types are necessary to meet the production schedule without an additional significant investment in the production facility. With this exception, the committee did not identify any specific technical problem in the proposed construction schedule of the fluorescence detector. On the other hand, it should be noted that the construction schedule entirely depends on the procurement of the PMTs and the construction of the fluorescence detector buildings, both of which are expected to be funded through the common fund and the contributions of local and federal Argentine governments. An adequate flow of these funds is essential to keep the construction schedule.

The final quality of the fluorescence detector data critically depends on the correction of atmospheric extinction. The collaboration intends to install a lidar system with a UV laser at each of the fluorescence detector stations and a horizontal extinction measurement system between fluorescence detector stations. A prototype lidar system will be installed at Los Leones in the near future and an extraction of the extinction coefficient will be tried in conjunction with the Engineering Array data acquisition. The committee stresses that a serious R&D effort on the atmospheric monitoring will be essential.

Another critical item affecting the fluorescence detector data quality is the precise knowledge of the atmospheric scintillation efficiency. At this moment, available data are limited and contain some conflicts, particularly for the 391 nm band which makes a major contribution for distant showers. Better understanding of the dependence of fluorescence extinction on pressure and humidity will greatly improve the accuracy of the fluorescence detector calorimetry. The collaboration is encouraged to pursue its plan to make a systematic survey of the scintillation efficiency including the use of high energy beams and showers created by such beams.

With the competency already shown in mounting the first two telescopes for the engineering array, the committee is confident that the collaboration is well prepared to deploy the full complement of 30 telescopes.

5. Project cost and finances

The committee was very pleased to hear that the Engineering Array will be completed well within the 1999 cost estimates, demonstrating that these estimates were reliable and conservative.
The cost of the construction and commissioning of the detectors are quite well known on the basis of the Engineering Array, and cost estimates have been stable over several years. This committee feels that these cost estimates are dependable and that the remaining uncertainties are covered by the contingencies assigned. As mentioned above, possible delays in the deployment of the detectors may increase the costs for temporary labor, but the increase is hardly significant on the overall scale of the project and can most likely be covered by the contingencies currently assigned.

As far as funding is concerned, the collaboration faces two problems: a funding shortfall of about 3 M$ in 2002, compared to the funding flow required to meet the ambitious schedule, and an overall funding shortfall of about 5 M$. In addition, it is not clear if all contributions by the participating countries and funding agencies will materialize in the promised amount. The overall funding situation could be eased if the central fluorescence eye were replaced by a northern eye, see below. The Finance Board is strongly urged to seek ways to ensure the required funding level in 2002, possibly by moving forward funding scheduled for 2003, and to seek ways to ensure the overall funding level.

6. Potential modifications of the array configuration

6.1 Northern vs central eye

The collaboration is currently discussing the replacement of the central fluorescence detector by a detector at the northern periphery with a reduced number of telescopes. The northern detector option would provide adequate coverage and result in significant savings (about 2 M$), at some expense in the number of events with multiple fluorescence detector views. Given the potential loss of observation time in the ground-level central eye due to fog, performance of the two options might be equivalent, resulting in a clear preference for the northern eye. Measurements will be carried out at the location of the central eye to quantify this aspect. The actual decision could be deferred for at most one year, without adversely affecting costs or schedule.

6.2 Size and shape of the ground array

Although financial considerations might suggest the need for a reduction in the number of surface detectors, the review committee urges the funding agencies to seek every means to avoid such a step. A reduction in the number of surface detectors should not be considered a viable solution; given the potentially lower flux of highest energy cosmic rays indicated by recent data, area coverage is of prime importance. The funding issue needs to be resolved within the next year.

7. Project management

Project Management – with the Fermilab-based project office – is responsible for the timely completion and operation of the Auger Observatory. Since the definition of the southern site, it was faced with the challenge of creating the most geographically extended research facility in the world at a remote location, more than 100 miles away from the nearest airport regularly served by commercial airlines. The lack of local industrial infrastructure and even of paved access roads and power supply to the locations where highly sophisticated scientific instruments have to be deployed, posed momentous technical, organizational, and logistical problems. An international collaboration comprising scientists from 18 countries was assembled in this harsh environment, under the management of two people that were only present on-site on a part-time basis. The success achieved to date is deemed by this committee as highly remarkable, and a proof not only of the experience and good judgement of the top managers, but also of the proficiency, expertise, and enthusiasm of the younger staff at different levels, including local and foreign scientists, most of them contributing to the project only for limited periods of time.

8. Education and outreach activities

The Auger collaboration has staged an impressive education and outreach program. The committee noted in particular the local activities in Malargüe, which have contributed significantly to the visibility of the project in Argentina, have helped to root it within the local community, and have contributed towards generating significant interest and support by the citizens of the province of Mendoza and by the local officials. Plans to expand this program and to equip the local Auger visitor center are strongly encouraged by the committee.

9. The northern array

The issue of the northern array has not been addressed by the collaboration in much depth, the reasons being that

- there is a consensus within the project management that a northern array must not distract work towards a timely installation of the southern array, and
- the physics motivation for a northern array as well as its required size will be influenced by the first data from the southern array; one year of data taking with the first 500 surface detectors should be able to prove or disprove AGASA´s claim for super-GKZ events.

The collaboration plans to have discussions concerning a northern array at its next collaboration meeting, and does not currently plan to go forward with a proposal before the southern array is well advanced. The committee supports this point of view, and feels that it is premature to make a strong statement at this time.

10. Summary

After spending several days with the Auger collaboration, the review panel came away with the feeling that the collaboration is strong and working very well together.

- Forty surface detectors have been installed in the Argentine pampa under quite difficult conditions.
- Electronics for 28 of these detectors is installed and working.
- Communications between the detectors and the central campus data acquisition system is operational.
- Triggering software and event building is operational.
- Two air-fluorescence detectors have been built and installed in a beautiful and functional building overlooking the southern portion of the surface array.
- Shower events trigger the air-fluorescence detectors and events are reconstructed and shown on an event display.
- Timing coordination of the surface array with the air-fluorescence system has been demonstrated and artificial (laser induced) hybrid events have been recorded and reconstructed.

Although the Engineering Array was not fully operational and the goal of demonstrating real hybrid events had not yet been achieved, it was clear that these goals would be demonstrated in short order. The management is very strong and seems to have the process under tight control. Some components used in the Engineering Array are being redesigned for the final production version and this will require some additional evaluation, but the panel concluded that there were no obvious obstacles to prevent the construction of the full array. The deployment schedule is very aggressive but given the performance in constructing the Engineering Array, there is every hope that it can be achieved. One serious concern is the flow of funds to maintain this schedule. If funding from the various countries is not received on a timely basis this could impact the schedule and the overall cost.